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Disclaimer

Abstract

The focus of this project is to demonstrate the effectiveness of Amended Silicate™ sorbents as a mercury control technology for coal-fired power plants. The demonstration will be conducted at Cinergy's Miami Fort Unit 6 for a period of six weeks under various conditions. In this first quarter of the project, the project team was assembled which includes ADA Technologies, Inc. and CH2M HILL who will carry out the project activities and the University of North Dakota Energy and Environmental Research Center, who will provide the continuous emissions monitors to measure mercury at the site and will serve as the QA/QC organization for the project. One the technical side, computational fluid dynamics (CFD) modeling was started to investigate methods to effectively disperse the sorbent material in Cinergy's Unit 6 flue gas ductwork.

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Executive Summary

The Amended Silicate™ sorbent technology is a mercury control material that is a direct replacement for activated carbon. Amended Silicates is a powdered material similar to carbon injected upstream of existing particulate control equipment for rapid and effective capture of vapor-phase mercury in the flue gas stream. This technology has been under development for the past two years with funding from the EPA and DOE, and has achieved success in demonstrating the sorbent at a pilot scale on a slipstream from a Colorado power plant. This demonstration of Amended Silicate™ sorbents will evaluate the control of mercury emissions from Cinergy's Miami Fort Unit 6 for a period of six weeks under various conditions. A consortium has been established to support the technical and financial requirements imposed by a long-term test of this technology. The consortium will include utilities with an interest in cost-effective mercury control technologies, mercury control technology suppliers (i.e., Amended Silicates, LLC and its parent companies); the University of North Dakota Energy and Environmental Research Center to lead the mercury measurement effort; a modeler to provide insight into the fluid mechanics of sorbent injection; with strong interest on the part of EPRI and the American Public Power Association.

The project has been defined in three stages: **preparation**, which incorporates all activities to prepare the host site for the demonstration, as well as the manufacture of 50-100 tons of Amended Silicate™ sorbent; **demonstration**, where a matrix of sorbent injection cases will be conducted; and **analysis**, during which all the collected data will be correlated, analyzed, and interpreted to provide quantitative information regarding the performance of the Amended Silicate™ sorbent at a commercial scale. ADA has established a series of milestones for these three stages as delineated in this report.

For this period, work consisted of tasks in the Preparation phase and Analysis phase. Activities focused on planning and on the initial analysis of the layout for the sorbent injection system via a computational fluid dynamics (CFD) modeling approach to the problem. Amended Silicates, LLC contracted with CH2M HILL to model the arrangement of sorbent injection ports on the host unit at Miami Fort station.

Amended Silicates also finalized the cooperative agreement with the US Department of Energy. Key to this agreement is Amended Silicates, LLC's contribution in the form of continued development in scaling up the manufacturing of the Amended Silicates sorbent to commercial-sized quantities. In addition, a subcontract was prepared, negotiated and executed with the University of North Dakota Energy and Environmental Research Center, who will provide the continuous emissions monitors to measure mercury at the site and to serve as the QA/QC organization for the project.

Introduction

Amended Silicates, LLC, has been awarded a project to demonstrate its Amended Silicates™ mercury removal sorbent technology in a full-scale trial at a coal fired power plant. The trial is to be hosted by Cinergy at a site in Ohio and funded in part by US Department of Energy's National Energy Technology Lab (NETL).

The Amended Silicate™ sorbent technology, a direct replacement for activated carbon, is a powdered sorbent injected upstream of existing particulate control equipment for rapid and effective capture of vapor-phase mercury in the flue gas stream. This technology has been under development for the past two years with funding from the EPA and DOE, and has achieved success in demonstrating the sorbent at a pilot scale on a slipstream from a Colorado power plant.

The Amended Silicate™ sorbents use silicate materials as substrate particles on which a chemical reagent with a strong affinity for mercury and mercury compounds is impregnated. Because of their physical construction, these silicates present extended surface area on each particle combined with an easily-generated particle size of a few microns. This configuration promotes maximum exposure of the chemical amendment to the mercury vapor present in the coal-fired flue gas stream. The base silicate materials typically sell for *4-8¢ per pound*, so they represent a very cost-effective sorbent material. In addition, because of their silicate content, they have been shown to allow the continued sale of fly ash as a pozzolan material. Tests completed by Boral Materials Technologies have indicated that there is no effect on fly ash use in concrete due to the addition of Amended Silicate™ sorbents, in dramatic contrast to the effect of powdered activated carbon injection.

To support EPA's announced intent to regulate the emissions of mercury from coal-fired power plants, NETL solicited proposals and recently has selected eight of those proposals for cost-shared projects to demonstrate mercury control concepts at a commercial scale. The objective of the program is to gather data to document the performance of mercury control technology alternatives when installed and operated at full-scale (100-MW) generating units. One of the selected proposals is for the demonstration of Amended Silicates™ sorbent technology.

This demonstration of Amended Silicate™ sorbents will evaluate the control of mercury emissions from Cinergy's Miami Fort Unit 6 for a period of six weeks under various conditions. A consortium is being established to support the technical and financial requirements imposed by a long-term test of this technology. The consortium will include utilities with an interest in cost-effective mercury control technologies, especially those that permit continued sale of fly ash as a pozzolan material; mercury control technology suppliers (i.e., Amended Silicates, LLC and its parent companies); an organization to lead the mercury measurement effort; a modeler to provide insight into the fluid mechanics of sorbent injection; and other interested parties. There is strong interest on the part of EPRI and the American Public Power Association in participating in the planned demonstration project.

Amended Silicates, LLC, is a joint venture company formed by ADA Technologies and CH2M HILL that is focused on the manufacture and sale of Amended Silicate™ sorbent. The Amended Silicates team will lead the technical effort of the proposed project. Cinergy has offered its Miami Fort Unit 6 as a host site, and will provide on-site technical support during injection of the sorbent material. The mercury semi-continuous emissions monitors (SCEMS) will be provided by the University of North Dakota's Energy and Environmental Research Center (UNDEERC), and the Ontario-Hydro wet chemistry testing will be conducted by the University of Western Kentucky. Boral Materials Technologies will perform tests of the collected sorbent plus fly ash to assess the impact of the added sorbent on the use of fly ash as a concrete additive. The ability to continue to sell fly ash is believed to be one of the significant advantages of Amended Silicate™ sorbents in comparison to activated carbon.

Project Description

This trial demonstration project is intended to show the effectiveness of Amended Silicate™ sorbent as a mercury control technology, including the ability to maintain fly ash sales from plants implementing its use. The project will incorporate three sorbent injection campaigns: one where powdered activated carbon is injected for a base-comparison case, a second where Amended Silicates sorbent is injected to establish process parameters required to meet mercury control targets, and a third where Amended Silicate sorbent is injected for a contiguous period of 30 days to validate long-term consistent performance and to discover any impact on balance of plant operation.

There are two major objectives for the full-scale demonstration project. The first is to produce uniform and high-quality Amended Silicate™ sorbent in multi-ton quantities for use in the proposed testing. The second is to demonstrate the ability of Amended Silicate™ sorbent to control emissions of mercury from commercial coal-fired power plants over a typical range of operating conditions for an extended period of time. The data analyses will be extensive, and will include computation of mercury removal rates and the efficiency of Amended Silicate™ sorbents in these applications.

The project has been defined in three stages: **preparation**, which incorporates all activities to prepare the host site for the demonstration, as well as the manufacture of 50-100 tons of Amended Silicate™ sorbent; **demonstration**, where a matrix of sorbent injection cases will be conducted; and **analysis**, during which all the collected data will be correlated, analyzed, and interpreted to provide quantitative information regarding the performance of the Amended Silicate™ sorbent at a commercial scale.

There are specific activities to be carried out in each stage of the project, as described below.

Preparation

- Project planning, including placement of subcontracts with team members and negotiation of a host site agreement with Cinergy.

- Development of a project schedule that reflects availability of the site, subcontractors, and time needed to prepare a commercial quantity of Amended Silicate sorbent.
- Site preparation, including the selection of locations for flue gas sampling ports and sorbent injection ports, and for the installation of a sorbent injection system to supply sorbent to the injection lances.
- Completion of a computational fluid dynamics modeling study to evaluate options for the number and locations of sorbent injection lances.
- Acquisition of a leased sorbent injection skid, fabrication of injection lances, and installation of the full sorbent injection system.
- Transport and installation of the semi-continuous mercury emissions monitors upstream of sorbent injection and at the outlet to the Unit 6 electrostatic precipitator.
- Preparation of 50 tons of Amended Silicate sorbent for use in the trial. This activity includes selection of a toll processor (contract vendor) to manufacture the sorbent, and oversight by Amended Silicates, LLC to assure quality control and consistency of the final product.

Demonstration

In the demonstration phase a series of campaigns will be completed with different sorbents to characterize their performance in capture of mercury from the flue gas of Miami Fort Unit 6. Mercury CEMs will be operated throughout the demonstration phase to collect data on mercury concentrations upstream of sorbent injection and at the outlet of the ESP of the host unit. At four discrete times in the demonstration, Ontario-Hydro wet chemistry sampling will be performed as a check against the mercury CEMs data. The specific mercury removal measurement campaigns are described below.

- Baseline mercury removal characterization for the host unit over a one to two week period.
- Injection of powdered activated carbon as a mercury sorbent on Miami Fort Unit 6. This campaign will run for one to two weeks, with target mercury removal rates of 55% and 80%.
- Injection of Amended Silicate sorbent in a parametric series of trials, to characterize performance in the host unit under a range of operating conditions. Target mercury removal rates will be 55% and 80% for this nominal two-week trial.
- Return to normal operations (no sorbent injection) for a period of one to two weeks to re-establish a baseline before initiation of a longer-term trial of Amended Silicates sorbent.
- Extended trial of Amended Silicate sorbent for a period of 30 days to evaluate performance and impact on balance of plant equipment.

- During each campaign, samples of fly ash mixed with mercury sorbent material will be extracted for use in tests to determine the effect of the sorbent on the use of the mixture as a pozzolan replacement in the manufacture of concrete.

Analysis

The use of CEMS results in the acquisition of a substantial quantity of data over the demonstration phase of the project. This information will be subject to a rigorous QA/QC review protocol, then archived to a project website where it will be accessible to project team members. This website will provide the home for a project database to be used to correlate mercury removal results with operating conditions of the host unit and performance of the particulate control equipment. The intent is to exploit the website to facilitate access to the data on a timely basis throughout the project. Specific activities to be carried out in the Analysis phase are noted below.

- Prepare and execute a QA/QC plan for the project.
- Establish a project website as a mechanism to share information and coordinate analysis of posted results.
- Create a project data base as a location to which all pertinent information on trials can be transferred for secure storage and analysis.
- Perform routine QA/QC screening of data and add qualified data to the project data base.
- Review and analyze trial data in the project data base to establish performance measures and trends in the data set.
- Analyze samples of fly ash plus sorbent to document the effect of sorbent addition on the use of fly ash as a cement replacement in concrete.
- Supply samples of fly ash to DOE contractor for leachate and mercury stability testing.
- Preparation of reports as required by the Cooperative Agreement.
- Preparation of technical papers that document the results of the trial demonstration.
- Overall management of the project with respect to scope, schedule, and budget.

Project activities are being carried out by technical personnel from the two parent companies of Amended Silicates, LLC. Jim Butz of ADA Technologies serves as Principal Investigator for the project with strong technical support from CH2M HILL and the other members of the consortium. Tom Broderick of ADA will serve as the lead engineer for the project team at the host site during the trial. Joe Hammond of CH2M HILL will direct the site engineering activity for the installation of the sorbent injection system and mercury CEMs.

Project Milestones

ADA has established a series of milestones for this project, as delineated below.

- **April, 2004:** Cooperative agreement signed by Amended Silicates, LLC and project initiated.
- **August, 2004:** Subcontracts in place, project team coordinates schedule.
- **December, 2004:** Toll manufacturer selected for manufacture of Amended Silicate sorbent material to be used in trial.
- **January 2005:** Start installation of sorbent injection system and mercury CEMs at the host site.
- **March 2005:** Deliver sorbents to site (powdered activated carbon and Amended Silicate sorbent).
- **March 2005:** Begin injection trial.
- **June 2005:** Submit samples of fly ash plus sorbent for analysis of suitability for use in concrete.
- **July 2005:** Samples provided for leachate and stability testing.
- **August 2005:** Data analyses completed.
- **Second half of 2005 and 2006:** Presentation of results at technical conferences.

Project Management Activities to Date

This report documents Amended Silicates project activities through June 30, 2004. For this period, work consisted of tasks in the Preparation phase and Analysis phase. Activities focused on planning and on the initial analysis of the layout for the sorbent injection system via a computational fluid dynamics modeling approach to the problem.

In this quarter, Amended Silicates finalized the cooperative agreement with the US Department of Energy. Key to this agreement is Amended Silicates, LLC's contribution in the form of continued development in scaling up the manufacturing of the Amended Silicates sorbent to commercial-sized quantities. In addition, the host utility, Cinergy Services Corp., will provide both in-kind and cash contributions to the required cost share of the project team.

Upon execution of the cooperative agreement, statements of work were prepared for the two companies who will carry out the project activities, ADA Technologies, Inc. and CH2M HILL. Both organizations use a Task Order arrangement to conduct business with Amended Silicates, LLC, so this mechanism was used to add them to the project team.

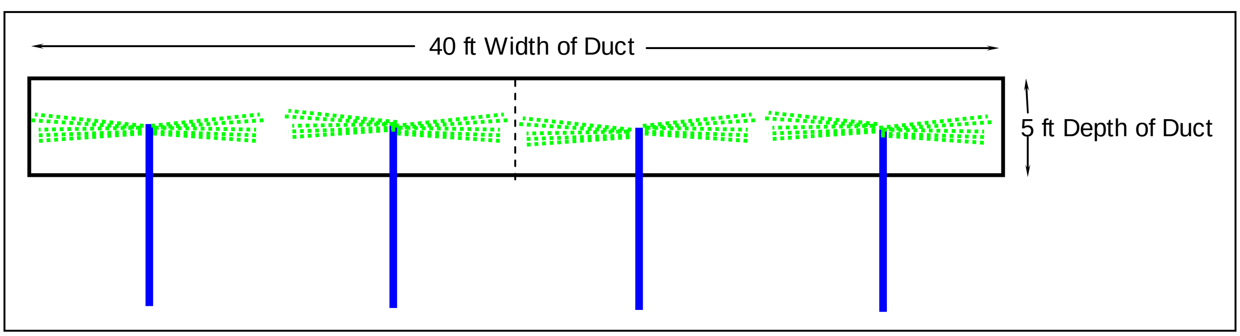
In addition, a subcontract was prepared, negotiated and executed with the University of North Dakota Energy and Environmental Research Center, who will provide the continuous emissions monitors to measure mercury at the site and to serve as the QA/QC organization for the project. UNDEERC is scheduled to provide a draft QA/QC plan by September 1st.

A meeting was held with J. Michael Geers of Cinergy to discuss the overall project plan, including details of Cinergy's role. The meeting agenda covered an overview of the elements of a host site agreement. Based on the information exchanged at that time, ADA Technologies has prepared a draft host site agreement, which is presently under review by Cinergy. That agreement should be finalized in the fall of 2004.

Experimental

Amended Silicates, LLC contracted with CH2M HILL to commence computational fluid dynamics (CFD) modeling efforts to investigate the arrangement of the sorbent injection ports on the host unit at Miami Fort station. The lead engineer for this task was supplied with a description of the unit as well as drawings of the exhaust ductwork between the combustion air preheater and the ESP. A second document was prepared that presented system performance requirements for the sorbent injection system, built upon use of a rental unit from Norit Americas. Parameters such as carrier air flow, sorbent delivery rates, and sorbent particle size distributions were included so that the CFD model could be employed to predict the mass loading of sorbent particles in the duct cross-section of the host unit. A baseline array of injection lances was defined for initial model runs, as shown as a schematic in Figure 1 below. It is important to note that the four injection lances are designed with opposing ports, which use carrier air to introduce sorbent particles into the flue gas orthogonal to the direction of its flow (out of the page in the Figure 1 layout). In this configuration, the injection lances are about ten feet apart, so to achieve rapid dispersion of the sorbent particles, the jets from the lance ports must penetrate about five feet into the flue gas (the green lines from the tips of the blue injection lances in Figure 1). The only motive force to drive the sorbent injection is that of the carrier air that transports the particles to the lances.

Figure 1. Layout for Sorbent Injection Lances for Miami Fort Unit 6 Ductwork



Results and Discussion

Initial runs of the sorbent distribution CFD model were made in June. A three-dimensional rendering of the Miami Fort Unit 6 ductwork is presented in **Error! Reference source not found.**. The light gray coloring marks the ductwork path within the larger, dark gray rectangular solid that mark the model boundary. The bright blue elements are turning vanes within the ductwork. The red lines labeled A and B mark the cross-sections at which particle distributions were computed by the CFD model, using the sorbent injection system parameters supplied to the modelers. The flow path in the ductwork is upward, from the outlet of the air preheater at the bottom of the rendering to the inlet to the first ESP on Unit 6 at the top. There are several directional changes in the flow path in addition to the turning vanes; each of these elements is seen in the modeling results to promote dispersion of the injected sorbent particles throughout the flowing flue gas. Sections are shown on the rendering- Section A-A is located ten feet above the sorbent injection location, and section B-B is 40 feet above injection.

Preliminary results of the CFD modeling are presented in Figure 3 and Figure 4 below. These present visualizations of sorbent particle concentrations and gradients at the elevations above injection noted in **Error! Reference source not found.**. The duct cross-section (a rectangle of dimensions 5 ft. by 40 ft.) is shown in different shades of purple close to the vertical and horizontal centers of the diagram. There are four injection locations modeled in this run, as previously indicated in Figure 1. The four red circles are centered on the injection lance ports, and indicate that by the time the flue gas has traveled an additional ten feet in the duct, there has been little dispersion of the sorbent particles. Indeed, the rapid change in color in the rings surrounding each lance strongly suggest that there is a very steep gradient in the sorbent concentration at this location.

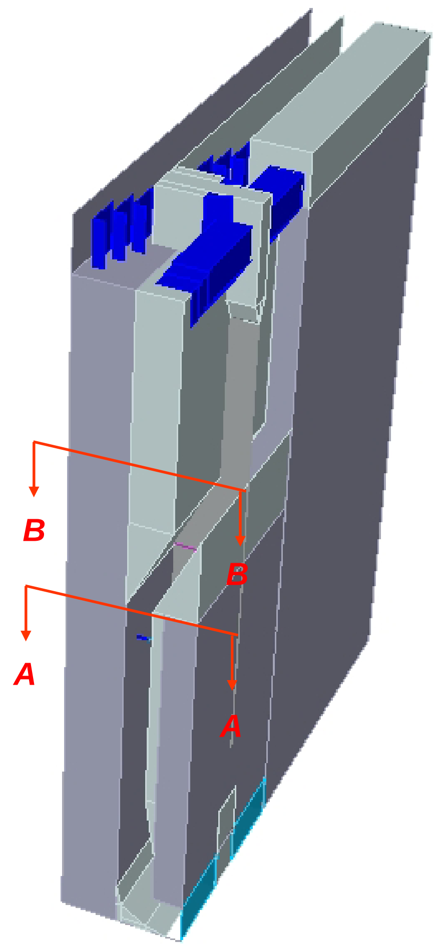
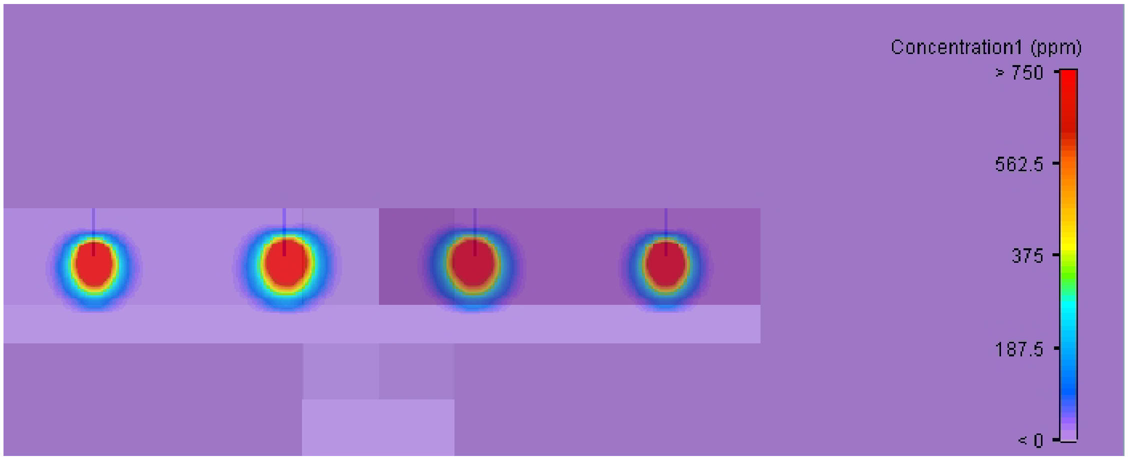


Figure 2. Model of Unit 6 Ductwork

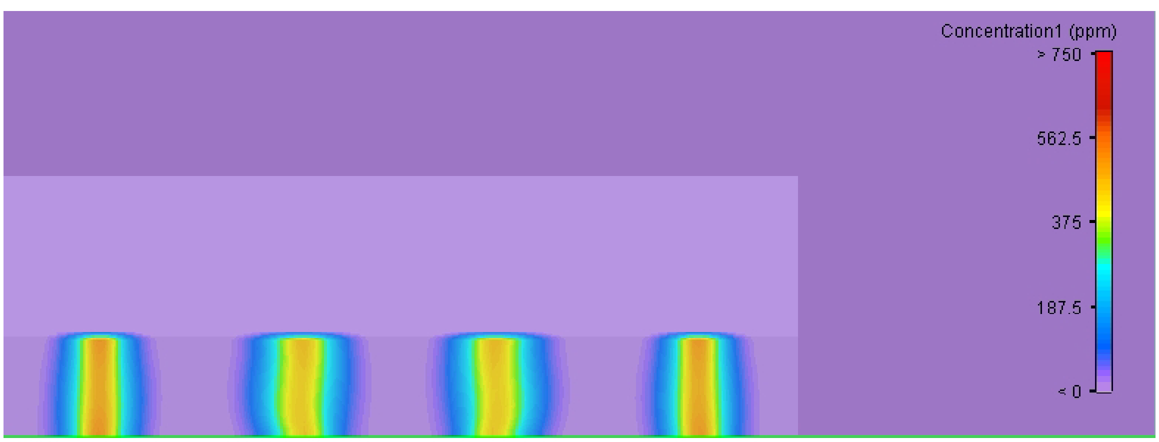
The image of Figure 4 shows a dramatic change in the dispersion pattern at a location only 30 feet further downstream from the dispersion pattern of Figure 3. In this case, it is important to note that there has been a shift in the location of the duct cross-section within the larger model boundary; the duct has moved to one edge of the boundary, shifting approximately the five-foot width of the cross-section. In this image, it is quickly seen that there has been considerable mixing in the short dimension, so that the color patterns which were formerly annular are now rectangular. However, it is also significant to note that there remains considerable gradients in the long dimension of the duct, as represented by the dark yellow to blue color variation seen moving left and right from each injection location.

Figure 3. Sorbent Particle Dispersion Gradients from CFD Model- 10 ft above Injection Location.



The image of Figure 4 shows a dramatic change in the dispersion pattern at a location only 30 feet further downstream from the dispersion pattern of Figure 3. In this case, it is important to note that there has been a shift in the location of the duct cross-section within the larger model boundary; the duct has moved to one edge of the boundary, shifting approximately the five-foot width of the cross-section. In this image, it is quickly seen that there has been considerable mixing in the short dimension, so that the color patterns which were formerly annular are now rectangular. However, it is also significant to note that there remains considerable gradients in the long dimension of the duct, as represented by the dark yellow to blue color variation seen moving left and right from each injection location.

Figure 4. Sorbent Particle Dispersion Gradients from CFD Model- 40 ft above Injection Location.



Also in this quarter ADA Technologies built a prototype injection lance in order to evaluate injection nozzle configuration details. The prototype lance was equipped with two different nozzle extensions, one where the interior was ground to match the curvature of the lance piping, and a second where the nozzle stub extended into the curvature to require a more tortuous path for the exiting two-phase flow of carrier air and sorbent. Tests of the prototype injection lance will be performed in the next quarter to determine the preferred design option for the nozzle extensions.

Conclusions

The modeling effort to date showed that four sorbent injection ports do not distribute the sorbent adequately in the ductwork. The CFD modeling efforts conducted in the next quarter will investigate the use of eight sorbent injection lances in the Unit 6 duct configuration.

References

None.

Bibliography

None.

List of Acronyms and Abbreviations

CEM	Continuous Emissions Monitor
CFD	Computational Fluid Dynamics
DOE	Department of Energy
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electric Static Precipitator
NETL	National Energy Technology Laboratory
QA/QC	Quality Assurance/Quality Control
SCEM	Semi- Continuous Emissions Monitor
UNDEER	University of North Dakota's Energy and Environmental Research Center
US	United States

Planned Activities for Next Quarter

The next quarter of the project will see continued efforts in the design and planning phases, including the following elements:

- Preparation of a draft QA/QC plan for review by the project team, to be written by UNDEERC as part of their subcontract.
- Presentation of project status at DOE's annual meeting of mercury contractors, planned for mid-July in Pittsburgh. In its role as the lead technical organization, ADA Technologies will be responsible for preparing and making the presentation.
- Continued work on a host site agreement, with the intent to execute the agreement in the next quarter. ADA will also lead this effort.

- Finish the Computational Fluid Dynamics modeling and finalize a configuration for the injection lances to be deployed at Miami Fort Unit 6. This task to be jointly directed by ADA and CH2M HILL.
- Run tests with the prototype lance to evaluate nozzle extension options. ADA to perform this task.
- Complete subcontract with Western Kentucky University to secure their participation in the project as the contractor who performs the Ontario-Hydro wet chemistry mercury testing. ADA Technologies to take the lead on this.
- Prepare reports to meet requirements of the cooperative agreement. ADA Technologies to complete these reports.
- Continue development and planning for large-scale manufacturing of Amended Silicates sorbent for use in the demonstration trial. CH2M HILL to lead this effort, funded by Amended Silicates, LLC.